VEGETATION CLASSIFICATION AND SURVEY

International Association for Vegetation Science (IAVS)

Vegetation Classification and Survey 5: 237–256
doi: 10.3897/VCS.114081

LONG DATABASE REPORT ECOINFORMATICS

IranVeg – the Vegetation Database of Iran: current status and the way forward

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Academic editor: Jürgen Dengler ♦ **Linguistic editor:** Megan J. McNellie
Received 12 October 2023 ♦ **Accepted** 29 September 2024 ♦ **Published** 19 December 2024

Abstract

Iran, situated in Southwest Asia, showcases a diverse landscape, including three phytogeographical regions and two global biodiversity hotspots. This diversity is attributed to its intricate geology, mountainous terrain, wide altitudinal range, and heterogeneous climate, fostering a rich flora characterized by a significant proportion of endemism. We present an updated version of the Vegetation Database of Iran (IranVeg) (GIVD ID AS-IR-001), comprising 13,411 plots spanning six major habitat types. These encompass deciduous forests (18.0%), woodlands and shrublands (5.6%), steppes and other grasslands (52.0%), saline depressions (9.3%), wetlands (12.2%), and anthropogenic habitats (2.9%), derived from 100 published and unpublished resources, comprising 3,919 plant species, belonging to 961 genera and 147 families. The vegetation data of Iran have been assigned to 31 valid and invalid phytosociological classes. The oldest plots were recorded in 1936 in the Alborz Mountains in northern Iran, while more than 60% of all plots were collected after 2010. Plot sizes vary from less than 1 m^2 to 10,000 m^2 with the highest species richness of 101 species recorded in a 25 m^2 montane grassland plot. IranVeg stands as the first national vegetation database in Iran, promising valuable insights into biodiversity patterns and facilitating the assessment of future environmental and anthropogenic changes. It remains open to further development through a collaborative network of vegetation scientists. This comprehensive database holds significant potential for advancing vegetation classification and survey efforts in Iran and beyond.

Taxonomic reference: World Flora Online (WFO 2024).

Keywords

biodiversity, Iran, macroecology, phytogeography, phytosociology, relevé, Southwest Asia, vegetation-plot database

GIVD Fact Sheet: Vegetation Database of Iran (IranVeg)

GIVD Database ID: AS-IR-001			**Last update:** 2024-09-30
Vegetation Database of Iran (IranVeg)		**Web address:**	
Database manager(s): Alireza Naqinezhad (anaqinezhad@gmail.com); Jalil Noroozi (jalil.noroozi@univie.ac.at); Soghra Ramzi (s.ramzi91@gmail.com)			
Owner: Consortium of the Vegetation Database of Iran (IranVeg Consortium). Individual datasets are owned by the data authors, lists of whom are available within the database.			
Scope: IranVeg is a national database from Iran. This database provides 13,411 vegetation plots from various habitats and vegetation types across the whole country.			
Abstract: Iran, encompassing a vast territory spanning 1,648,195 km2, features altitudes ranging from 26 m b.s.l. to 5,671 m a.s.l. at Mount Damavand. The country exhibits a diverse range of climatic conditions, from arid regions with less than 50 mm of precipitation in central deserts to areas in the north receiving over 2,000 mm of precipitation annually. This ecological diversity gives rise to various ecosystems and vegetation types across Iran. The IranVeg database represents a significant initiative aimed at creating a comprehensive repository of Iran's vegetation. This database, which is both geographically and floristically representative at the national level, holds immense value for analyzing biodiversity patterns and forecasting future changes in the region. Its growth is anticipated through the continuous addition of new data contributed by vegetation scientists. The database currently comprises 13,411 vegetation plots. These plots represent a wide array of vegetation types found in Iran, including deciduous forests (18.0%), woodlands and shrublands (5.6%), steppes and other grasslands (52.0%), saline depressions (9.3%), wetlands (12.2%), and anthropogenic habitats (2.9%).			
Availability: according to a specific agreement		**Online upload:** no	**Online search:** no
Database format(s): TURBOVEG, Excel		**Export format(s):** TURBOVEG, Excel, CSV file, plain text file	
Plot type(s): normal plots, nested plots		**Plot-size range (m²):** 0.0001 to 10000	
Non-overlapping plots: 13411	**Estimate of existing plots:** 20000	**Completeness:** 67%	**Status:** completed and continuing
Total no. of plot observations: 13411	**Number of sources (biblioreferences, data collectors):** 100		**Valid taxa:** 3919
Countries (%): IR: 100			
Formations: Forest: 18% = Terrestrial: 18% // Non Forest: 82% = Aquatic: 3%; Semi-aquatic: 9%; Terrestrial: 70% (Arctic-alpin: 8%; Non arctic-alpin: 62% [Natural: 59%; Anthropogenic: 3%])			
Guilds:			
Plot size categories (%): < 1 m2: 24.3%; 1-10 m2: 17.7%; 10-100 m2: 28.8%; 100-1000 m2: 19.9%; 1000-10000 m2: 1.0%; >= 10000 m2: 0%; unknown: 8.3%;			
Environmental data (%): altitude: 80; slope aspect: 50; slope inclination: 60; microrelief: 9; surface cover other than plants (open soil, litter, bare rock etc.): 38; other soil attributes: 21; soil pH: 29; land use categories: 16; other attributes: organic matter (21), nitrogen (22), phosphorus (13), potassium (14), calcium carbonate (11), electrical conductivity (17), sand (25), silt (25), and clay (25)			
Performance measure(s): presence/absence only: 10.8%; cover: 89.2%			
Geographic localisation: GPS coordinates (precision 25 m or less): 70.6%; political units or only on a coarser scale (above 10 km): 29.4%			
Sampling periods: before 1920: 0%; 1920-1929: 0%; 1930-1939: 0.2%; 1940-1949: 0%; 1950-1959: 0.1%; 1960-1969: 0.1%; 1970-1979: 5.3%; 1980-1989: 1.1%; 1990-1999: 6.4%; 2000-2009: 25.7%; 2010-2019: 58.9%; after 2020: 2.1%; unknown: 0%			
Information as of 2024-10-01; further details and future updates available from http://www.givd.info/ID/AS-IR-001			

Introduction

Iran, located in Southwest Asia and spanning over 1,648,000 km² between 25° and 40° northern latitude and 44° and 63° eastern longitude, features a diverse topography with approximately 62% of its terrain situated above 1,000 m a.s.l. (Noroozi et al. 2019a). The country has been called a country of extremes in SW Asia (Akhani 1998) and elevation varies from 26 m b.s.l. on the southern Caspian Sea shores to 5,671 m a.s.l. at the summit of Mt. Damavand, the highest summit in SW Asia. The country encompasses three macrobioclimatic zones – temperate, mediterranean and tropical – yielding ten bioclimates defined by temperature and precipitation (Djamali et al. 2011). Annual precipitation ranges from below 30 mm in the desertic Dasht-e-Lut, in southern Iran, to above 2,000 mm in the Hyrcanian deciduous forests of the north (Akhani et al. 2010; Gholizadeh et al. 2020). Mean temperatures of the coldest and warmest months vary from -13.3 °C in Firuzkuh (Alborz Mts) to 47.5 °C in the Kerman deserts (Djamali et al. 2011). Furthermore, Iran's geological structure is intricate, characterized by formations of diverse origin (plutonic, volcanic, sedimentary, and metamorphic), age (Precambrian to Quaternary) and composition (Stöcklin 1968; Berberian and King 1981).

The huge climatic, topographic and edaphic variation lead to a rich floral history and high evolutionary potential (Klein 1990; Akhani 1998). The country lies at the interface of three phytogeographical regions: the "Euro-Siberian" along Caspian Sea shores in the north, the "Irano-Turanian" covering most of the country, and the "Saharo-Sindian" along the Persian Gulf and the Oman Sea in the south (Zohary 1973; Léonard 1981–1989). This environmental and phytogeographical diversity fosters a rich floristic diversity of the country embracing more than 8,000 vascular plant species, 32% of which are endemics (Noroozi et al. 2019a). Notably, Iran hosts two global biodiversity hotspots (Caucasian and Irano-Anatolian; Mittermeier et al. 2011) and five areas of endemism, i.e. Zagros, Alborz, Azerbaijan Plateau, Kopet Dagh-Khorassan, and Yazd-Kerman (Noroozi et al. 2019a, 2019b).

The northern slopes of the Alborz Mountain range, extending from the Caspian Sea shores up to 2,800 m a.s.l.,

are covered by temperate deciduous Hyrcanian forests, a UNESCO World Heritage Site (World Heritage Convention 2019). These forests preserve the phylogenetic heritage of the late Tertiary period, housing endemic Arcto-Tertiary floristic elements (Bobeck 1951; Browicz 1989; Frey et al. 1999; Gholizadeh et al. 2020; Ghorbanalizadeh and Akhani 2022). In the Zagros Mts, the largest mountain range of Iran, the "Kurdo-Zagrosian oak steppe-forest" (*sensu* Zohary 1973) is dominated by diverse *Quercus* species distributed throughout (Sabeti 1976; Sagheb Talebi et al. 2014; Ambarlı et al. 2018, 2020). While the mountains harbor the bulk of Iran's flora and endemics, the central plateau is characterized by low species richness (Zohary 1973; Frey and Probst 1986; Léonard 1991–1992; Noroozi et al. 2019a, 2019b). The harsh and dry conditions prevailing in this region due to low rainfall and high evaporation rates, support primarily xerophytic species. Dominant vegetation types include xerophytic pistachio-almond forest-steppes, *Artemisia* steppes, psammophytic vegetation and halophytic vegetation in saline depressions (Zohary 1973; Frey and Probst 1986; Léonard 1991–1992; Ghahreman and Attar 1999; Asri 2003; Akhani 2004). Moreover, steppes and grasslands including thorn-cushion and dwarf shrubland vegetation predominantly cover the vast mountain ranges of Iran (Zohary 1973; Noroozi 2020). The presence of two distinct coastal regions, along the Caspian Sea in the north and bordering the Persian Gulf and Oman Sea in the south, further enriches Iran's biodiversity. These coastal habitats, characterized by specific vegetation and habitat types, face various threats, as noted by Tirgan et al. (2022) for the south Caspian coastline. The coastal regions on the Persian Gulf are characterized by *Acacia* and *Prosopis* semidesert shrublands and mangroves (Frey and Probst 1986; Léonard 1991–1992; Akhani and Ghorbanli 1993; Akhani and Samadi 2015).

Despite its location in the arid region of Southwest Asia, Iran boasts 26 internationally recognized Ramsar wetland sites, covering approximately 1% of its total surface area, as reported by the Ramsar Organisation (Convention on Wetlands Secretariat 2024). Moreover, montane wetlands, including fens, bogs, riverine, and spring types, are dispersed across the steppe-covered mountains of Iran, and play a vital role in biodiversity conservation. Many of them exist as isolated, patchy, and remote habitats within the broader arid environment, functioning as ecological oases. These spot-like wetlands support highly unique and specialized ecosystems, providing refuge for rare and endangered flora and fauna (Kürschner and Djamali 2008; Djamali et al. 2009; Naqinezhad et al. 2019; Fensham et al. 2023). Studies by Jalili et al. (2014) and Naqinezhad et al. (2021) emphasize their significance, underlining the crucial role these habitats play in preserving biodiversity, despite their limited and fragmented distribution.

The history of botanical surveys in Iran is rich, with contributions from distinguished publications such as Boissier (1867–1888), Parsa (1943–1980), Rechinger (1963–2015), Assadi et al. (1988–2024) and Ghahreman (1976–2007). Subregional floras complement national efforts, including for example "Flora of Ilam" (Mozaffarian 2008), "Flora of Gilan" (Mozaffarian 2019), "Illustrated Flora of Golestan National Park" (Akhani 2005, 2023), "Illustrated Flora of Alborz Mountain Range Iran" (Noroozi and Talebi 2023) and many others.

Pioneering efforts in vegetation description, classification and mapping using physiognomic-ecological approach by Bobeck (1951), Zohary (1963, 1973), Mobayen and Tregubov (1970), Probst (1972, 1981), Frey and Probst (1977, 1986), Frey and Kürschner (1979), Frey (1980) and Frey et al. (1999) laid the foundation for subsequent research. In a paper entitled "On the geobotanical structure of Iran", Zohary (1963) was the first to tentatively describe 54 associations from 26 classes in all parts of the country using a physiognomic/ecologic survey. However, all these associations are considered as "nomina nuda" due to inappropriate descriptions of associations and vague lists of associated species (Léonard 1993; Theurillat et al. 2021). Phytosociological studies further elucidated specific habitat types, including forests and woodlands (Djazirei 1964, 1965; Mossadegh 1971; Dorostkar and Noirfalise 1976; Assadollahi 1980; Rastin 1980, 1983; Akhani and Ziegler 2002; Hamzeh'ee et al. 2008; Ravanbakhsh et al. 2018; Gholizadeh et al. 2020; Karami-Kordalivand et al. 2021; Esmailzadeh and Soofi 2022), alpine and montane steppes (Gilli 1939; Klein 1984, 1987; Klein and Lacoste 1994, 1999; Noroozi et al. 2010, 2014, 2017; Akhani et al. 2013; Mahdavi et al. 2013; Naqinezhad and Esmailpoor 2017), lowland steppes, inland and coastal dunes (Léonard 1991–1992; Asri 2003; Naqinezhad 2012a; Mahdavi et al. 2017; Tirgan et al. 2022), wetlands (Asri and Eftekhari 2002; Asri and Moradi 2006; Asri et al. 2007; Naqinezhad et al. 2009, 2021; Kamrani et al. 2011), and halophytic and saline vegetation (Carle and Frey 1977; Akhani and Ghorbanli 1993; Asri and Ghorbanli 1997; Asri 1999; Alaie 2001; Akhani 2004, 2006; Ghorbanalizadeh et al. 2020; Ghorbanalizadeh 2022). In addition to phytosociological studies, some research endeavors aimed to assess various elements of biodiversity along environmental gradients (Rahmanian et al. 2020, 2023; Talebi et al. 2021) and to implement biodiversity monitoring, examining the impacts of various management regimes (Valadi et al. 2022; Sanaei et al. 2023; Bashirzadeh et al. 2024).

Vegetation-plot databases play a pivotal role in large-scale analyses such as vegetation classification and mapping, floristic diversity studies, habitat management, biogeographical analysis and biodiversity assessment and monitoring (Wiser 2016; Chytrý et al. 2020; Loidi et al. 2021; Sabatini et al. 2022). Accessing data sources becomes crucial particularly when conducting synthetic analyses to tackle overarching ecological challenges within macroecological objectives (Madin et al. 2007). Over the years, millions of vegetation plots have been meticulously recorded and partially digitized for specific local purposes (Dengler et al. 2011; Bruelheide et al. 2019). To address deficiencies in vegetation survey data and bridge the gap between community ecology and macroecology, it is imperative to amalgamate individual vegetation datasets into comprehensive databases that span expansive geographic regions (Dengler et al. 2011, 2018; Wiser 2016; Sabatini et al. 2021).

Iran's vegetation data, collected since the 1930s through extensive fieldwork, have now been consolidated into the IranVeg database, representing an important national effort to catalog and organize the country's diverse plant communities. This comprehensive resource aims not only to provide a platform for advancing vegetation ecology research but also to address critical questions related to biodiversity conservation, ecosystem services, and climate change resilience. The IranVeg database offers a wealth of information for researchers, conservationists, and policymakers alike, facilitating large-scale analyses of vegetation patterns, species distributions, and habitat dynamics across Iran's varied landscapes. By integrating decades of field observations with modern analytical tools, it paves the way for interdisciplinary studies, fostering collaborations between community ecology, macroecology, and conservation biology. This paper offers a detailed overview of the IranVeg Vegetation Database, highlighting its foundational objectives, methodological framework, and the transformative potential it holds for future ecological research and sustainable development in Iran and beyond. With this database, we hope to inspire and empower vegetation scientists and ecologists to explore new frontiers in understanding vegetation and plant biodiversity in arid and semi-arid regions of Western Asia and beyond.

Database development, structure and management

The Vegetation Database of Iran (IranVeg) was unveiled during the 9th International Meeting on Vegetation Databases at Hamburg University, Germany, in February 2010. At the meeting, the Global Index of Vegetation-Plot Database (GIVD) was launched (Dengler et al. 2010), and a total of 2,000 plots were registered in GIVD as the "Vegetation Database of Iran" (ID AS-IR-001). This dataset was described in a special volume of "Biodiversity and Ecology" dedicated to the meeting (Naqinezhad 2012b). Additionally, three smaller datasets were also registered in GIVD, namely the "Vegetation database of mountain wetlands" (ID AS-IR-002; Naqinezhad 2012c), the "Vegetation database of the Hyrcanian area" (ID AS-IR-003; Naqinezhad 2012d) and the "Alpine Vegetation of Iran" (ID AS-IR-004). By 2015, these datasets were consolidated into a unified national database, retaining the GIVD ID AS-IR-001, comprising a total of 2,335 plots.

IranVeg is a self-governed consortium in which every data contributor becomes a member. The Custodian and a Deputy Custodian were provisionally elected to coordinate the database, with A. Naqinezhad the current Custodian and J. Noroozi and S. Ramzi the Deputy.

Since January 2022, we have initiated a comprehensive work plan to update the Vegetation Database of Iran and add newer data. This involved conducting a thorough survey of all available vegetation literature and collaborating with authors. Consequently, our database consists of data from published resources by either digitizing old literature or access to direct stored excel spreadsheets/TURBOVEG xml files of the authors (68%) and unpublished data (32%) (Suppl. material 1).

Management of the database is done with TURBOVEG (Hennekens and Schaminée 2001). All data have been sourced directly from the original references. In addition to the comprehensive list of plant species, some plots also contain recorded environmental data such as altitude, slope, aspect, and physical and chemical soil characteristics. Coordinates have been meticulously handled. While some were directly reported with GPS precision, others were derived from the central point of the study area (county, city, village, specific site, etc.) using Google Earth engine with a precision of 5 km. To ensure consistency, all coordinates have been standardized and are presented in decimal degrees throughout the dataset. The species nomenclature was standardized using the *U.Taxonstand* package in R (Zhang and Qian 2023), and harmonized with the World Flora Online database (WFO 2024).

Finally, we assigned the plots in IranVeg to six major habitat types to better describe them. This classification was not based on statistical analysis but was rather a descriptive grouping. However, since phytosociological classification analyses have been performed on most of the sources from which the plots were extracted, we were able to assign these plots with greater accuracy. Species richness was also reported within these predefined groups. Given that plot size is an important driver of biodiversity, we excluded plots with sizes outside the central 95% percentile when reporting area/species richness relationship in each habitat.

Database content

The updated edition of the "Vegetation Database of Iran (IranVeg)" now comprises 13,411 plots spread across Iran, averaging 0.8 plots per 100 km^2, with a notable concentration in the northern regions (Figure 1). The plots in IranVeg in question likely account for approximately 67% of all plots surveyed in Iran, exhibiting substantial overlap with 392 plots in GIVD ID: AS-IR-005 (Mahdavi and Akhani 2015) and 1,597 plots in GIVD ID: AS-IR-006 (Gholizadeh et al. 2019). The majority of the recorded plots have been collected through vegetation surveys based on the phytosociological approach, while the remainder consists of biodiversity and monitoring plots, including 209 series of nested plots spanning various habitat types.

Out of 13,411 plots compiled in IranVeg, 7,375 have already been included in the emerging version 4.0 of the global database sPlot (https://www.idiv.de/en/sdiv/working-groups/wg-pool/splot/splot-database.html; see Bruelheide et al. 2019) and 2,875 in the Palaearctic database GrassPlot, version 2.00 (Dengler et al. 2018; Biurrun et al. 2019).

The predominant methods of vegetation survey employed by vegetation ecologists working in Iran were the 7-step and 9-step versions of the Braun-Blanquet cover-abundance scales, derived from the Zurich-Montpellier

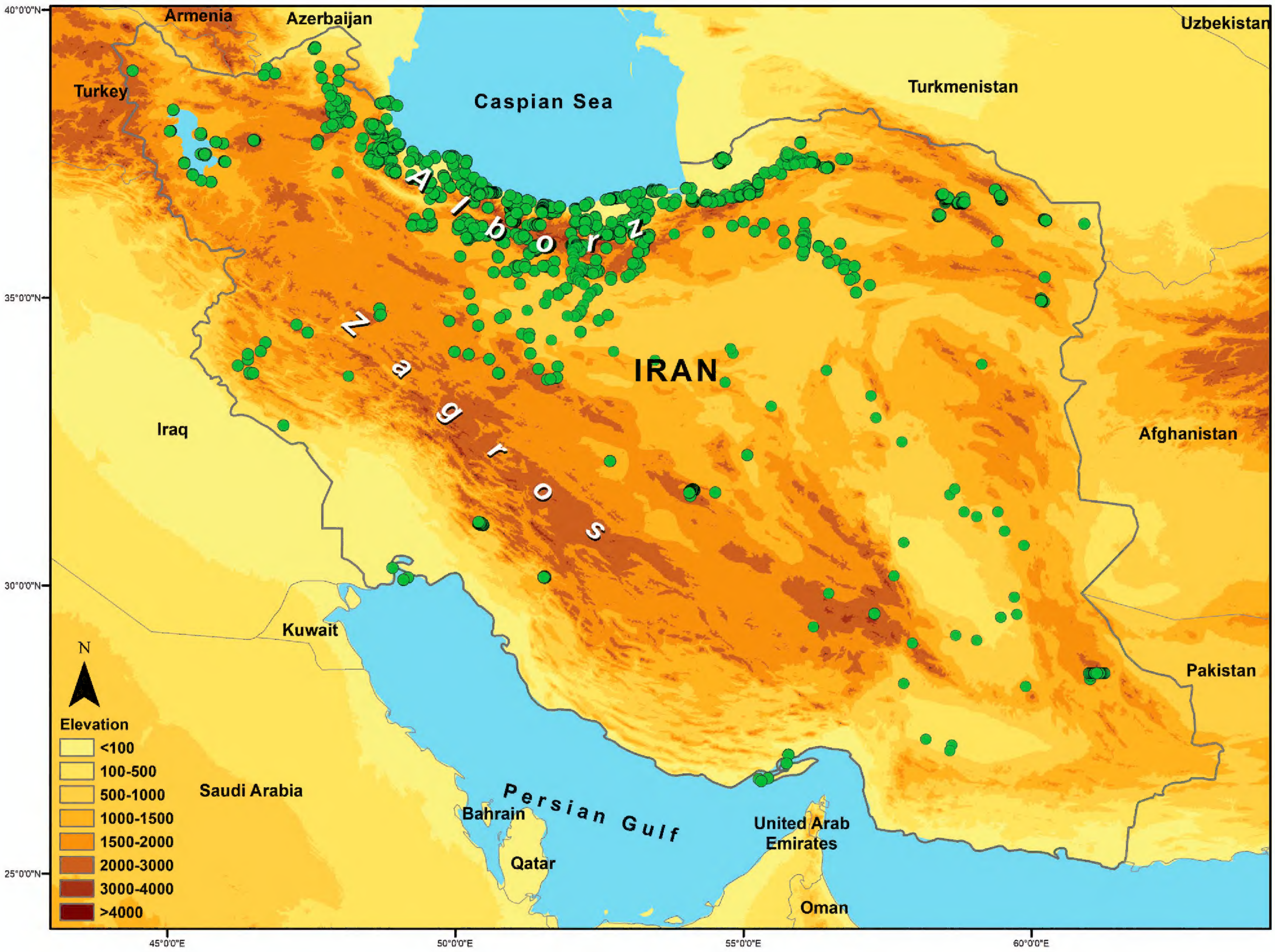

Figure 1. Topographic map of Iran showing the spatial distribution of IranVeg plots across the country.

School (Braun-Blanquet 1964). As a result, the majority of the registered plots (58.9%) have been collected utilizing these scales. Additionally, the vegetation cover of 27.1% of plots was represented in direct percentage (see Dengler and Dembicz 2023), 10.8% as presence/absence, 2.3% with the van der Maarel scale (van der Maarel 1979) and 1.0% on the Londo scale (Londo 1976).

Plot sizes varied wildly from less than 1 m^2 to 10,000 m^2, while in 8.4% of the plots size was not reported (Fact Sheet, Figure 2). The oldest plots were recorded in the 1930s (1936) in the high regions of the Alborz Mountains in northern Iran (Gilli 1939). Notably, there were no additional reports in the 1940s, and more than 60% of plots were recorded after 2010 (Fact Sheet, Figure 3). About 71% of plots were georeferenced with GPS coordinates at a precision of 25 m or less, while the coordinates for others were derived from the central point of the study area (county, city, village, specific sites, etc) using Google Earth engine with a precision of 5 km (Fact Sheet).

The dataset encompasses several crucial environmental variables. The most frequently recorded variables are altitude, slope, and aspect recorded in 80%, 60%, and 50% of the plots, respectively. Furthermore, some plots have documented edaphic factors from which pH (28.7%), and physical soil characteristics such as the proportions of sand, silt, and clay (25%) constitute the most recorded soil data (Table 1).

IranVeg comprises records of 3,912 species of vascular plants and seven species of bryophytes, distributed across 961 genera and 147 families. The dominant families include *Asteraceae*, *Fabaceae* and *Poaceae*, with *Astragalus* being the most species rich genus in the database. Species richness within the stored plots varies, ranging from 1 (in plots of 4, 16 and 25 m^2) to 101 (in 25 m^2), with approximately two-thirds of the plots containing fewer than 20 species.

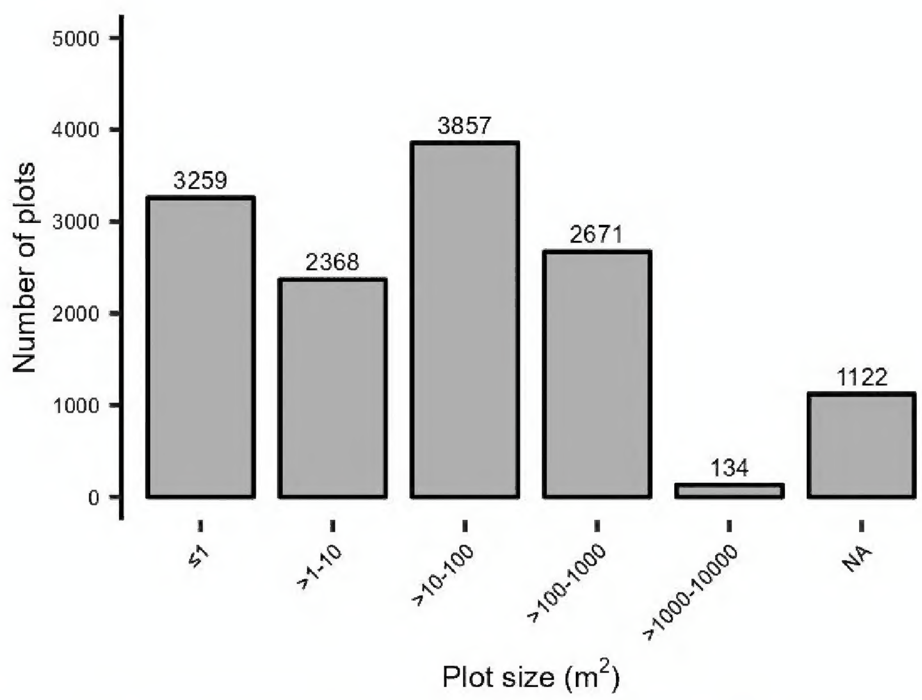

Figure 2. Plot size distribution in the IranVeg database. NA: plots without size information.

Table 1. Environmental variables recorded in the IranVeg database.

Variable	Measurement unit	Availability in the database (%)	Min.	Max.	Mean	Median
Altitude	m a.s.l.	80	-26	4799	2019	2100
Slope	°	60	0	85	23	22
Slope aspect	°	50	0	360	142	140
Total cover	%	32	0.2	165	64	70
Microrelief	cm	9	0	400	48	30
Organic matter	%	21	0.03	47.7	7	6.2
pH	-	29	2.7	8.8	7	6.9
N	%	22	0	5.3	0.4	0.4
P	ppm	13	0	122	16	4.4
K	ppm	14	3.9	4022	470	346
$CaCO_3$	%	11	0.5	37.5	2	6.2
Electrical conductivity	μS/cm	17	0.15	4280	242	112
Sand	%	25	0	99.7	50	54.9
Silt	%	25	0.06	66.7	24	24
Clay	%	25	0	71	18	14.6

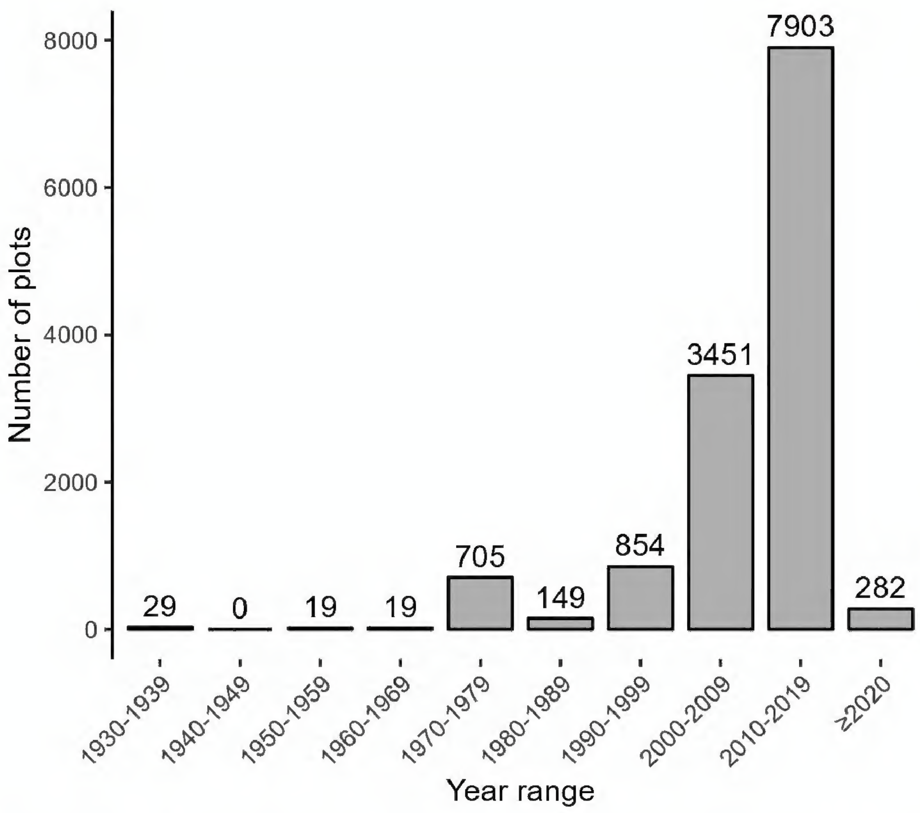

Figure 3. Temporal distribution of vegetation plots included in the IranVeg database (1936–2023).

Major habitat types

Given that the compilation of Iranian vegetation data is an ongoing project and still far from completion, any classification of habitats or large physiognomic vegetation types should be grounded in the plots collected thus far. Currently, based on the available plot data, six major habitat types can be distinguished in IranVeg.

1) Deciduous forests: The deciduous temperate forest in northern Iran represents 18.0% of the plots in the database (Figures 4, 5). These plots are characterized by notable species richness, typically containing 20 to 40 species per plot, with sizes ranging from 20 to 400 m^2, with an average size of 371 m^2 (Figure 6). Hyrcanian forests are generally categorized into four main elevational zones: lowland, submontane, montane and upper-montane (see Gholizadeh et al. 2020). Dominant tree species in these forests include *Fagus orientalis*, *Carpinus betulus*, *Quercus castaneifolia*, *Q. macranthera*, *Parrotia persica*, *Alnus glutinosa*, *A. subcordata*, *Populus caspica* and *Pterocarya fraxinifolia* (Akhani et al. 2010; Sagheb Talebi et al. 2014) (Figures 7a–c).

Recent comprehensive phytosociological surveys of the Hyrcanian forests identified eight alliances and 26 associations belonging to five orders and four classes, namely *Alnetea glutinosae*, *Alno glutinosae-Populetea albae*, *Carpino-Fagetea sylvaticae* and *Quercetea pubescentis* (Gholizadeh et al. 2020; Karami-Kordalivand et al. 2021; Esmailzadeh and Soofi 2022). A large number of plot data used in the datasets were extracted from old doctoral theses and related publications carried out by some European institutions (Djazirei 1964, 1965; Mossadegh 1971, 1981; Dorostkar 1974; Dorostkar and Noirfalise 1976; Assadollahi 1980; Rastin 1980, 1983; Assadollahi et al. 1982; Klein and Lacoste 1989).

2) Woodlands and shrublands: Woodlands and shrublands account for 5.6% of all plots in the current database (Figures 4, 5). Species richness in most plots of this major habitat type ranges from 1 to 20 species per plots, with sizes ranging from 2 to 400 m^2 and an average of 180 m^2, with the highest recorded richness being 87 species in a plot of 16 m^2 (Figure 6). This major habitat type comprises plots accommodated in various drought-adapted "forest/shrubby steppes" dominated by oak, juniper, pistachio-almond and *Acacia-Prosopis* in the Irano-Turanian and Saharo-Sindian regions of Iran (Frey and Probst 1986; Erdős et al. 2018; Noroozi et al. 2020; Ambarlı et al. 2020). Along the Zagros Mountain ranges, the climax vegetation is an open xerophytic cold-resistant deciduous oak woodland steppe which dominates between 1,000 and 2,000 m a.s.l. and accounts for almost 40% of Iran's forests/woodlands (Sagheb Talebi et al. 2014) (Figure 7d). Zohary (1973) described this formation as "Kurdo-Zagrosian oak steppe-forest" which forms a rather broad belt in western and southwestern Iran to Iraq. *Quercus brantii*, *Q. infectoria*, and *Q. libani* are dominant species in these habitats. Moreover, the arid and semi-arid gentle slopes of the mountains of Iran are mainly covered by open xerophytic scrub/shrub communities. These communities were named

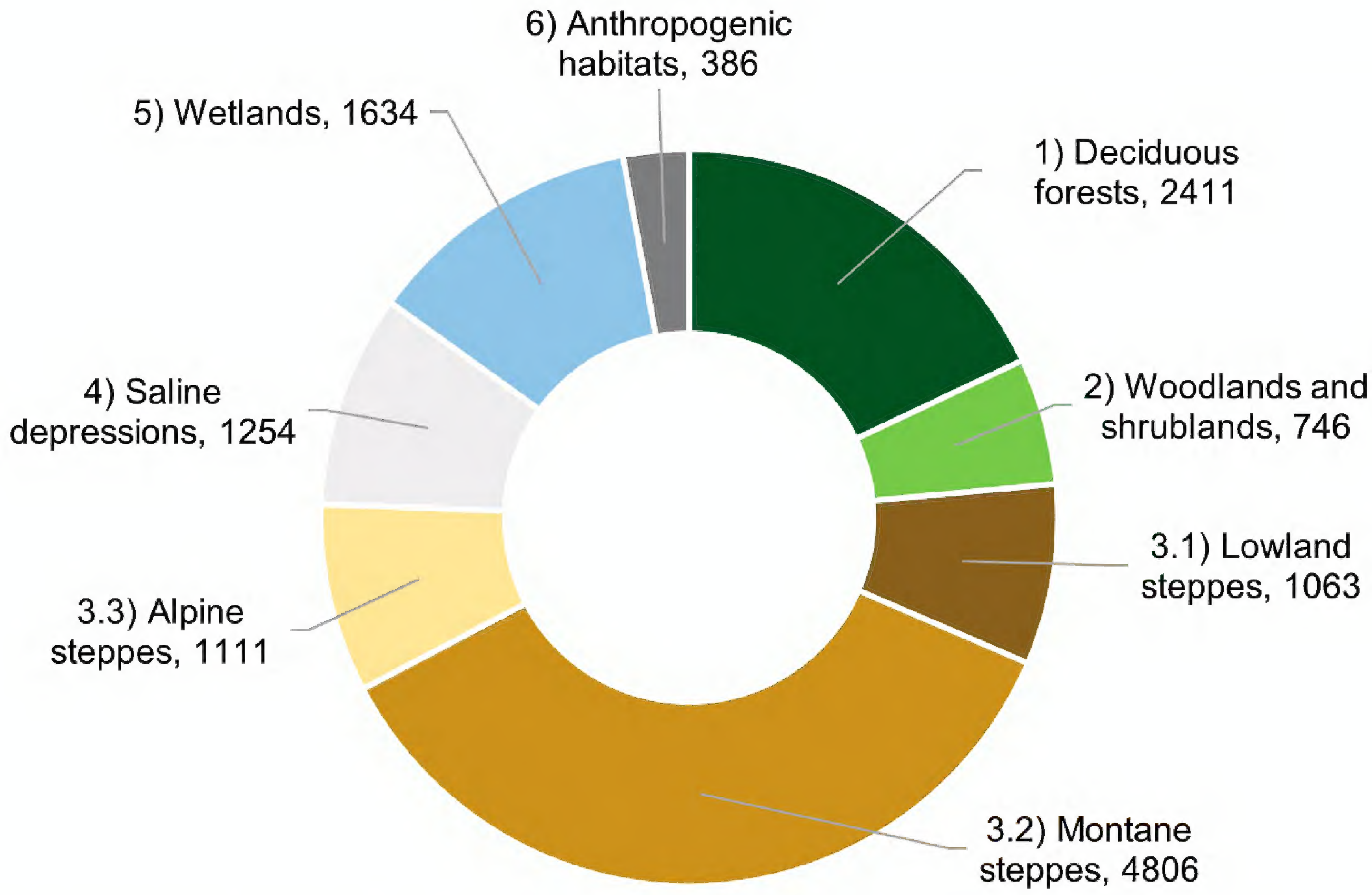

Figure 4. Distribution of vegetation plots in the IranVeg database across major habitat types.

"Pistazien-Mandel-Ahorn-Trockenwald" by Bobeck (1951) and "*Juniperus-Pistacia-Amygdalus*-steppe scrub" by Zohary (1973). This pistachio-almond shrub steppe is generally characterized as a transitional community located on rather gentle slopes between lowland *Artemisia*-dominated desert steppe areas and thorn-cushion formations of montane steppe, and is characterized by *Pistacia atlantica*, *P. khinjuk* and *Prunus scoparia* as the main species (Figure 7e). Long-term land use and overgrazing have degraded these woodlands (Djamali et al. 2008, 2011), leading to their replacement by thorn-cushion montane steppes at higher altitudes and *Artemisia* steppes at lower altitudes (Djamali et al. 2011). Our vegetation database also embraces plots from juniper woodlands in the montane and subalpine zones of the Iranian mountains up to 3,000 m a.s.l. (Zohary 1973; Frey and Probst 1986; Ravanbakhsh et al. 2016). These woodlands, which range from sparsely distributed to dense forest-like, occur almost at the same elevation band of montane thorn-cushion steppes and are intermixed with such communities (Memariani et al. 2016). The main species on the dry southern slopes are *Juniperus polycarpos* and associated species (see Memariani et al. 2016; Hojjati et al. 2018) which are different from the carpet-like formations of *J. communis* and *J. sabina* that cover the subalpine zone of the northern humid slopes of the Alborz Mts (Figure 7f). Moreover, the relict Mediterranean woodland community of *Cupressus sempervirens* on the northern slopes of Alborz Mts, can be added to this group (Zohary 1973; Frey and Probst 1986) (Figure 7g). The group of woodlands and shrublands also includes extremely xeromorphic savanna-like woodlands in the Saharo-Sindian region of southern Iran, where *Vachellia tortilis*, *V. oerfota*, *V. flava*, *Prosopis cineraria*, *P. koelziana*, *Ziziphus spina-cristi* and *Haloxylon salicornicum* are the dominant species (Frey and Probst 1986; Hamzeh'ee 1999; Nadjafi Tirehe-Shabankareh et al. 2006; Akhani and Samadi 2015) (Figure 7h).

The syntaxonomic classification of this habitat type is still far from complete. There are 10 validly published associations from this habitat, belonging to four alliances, four orders and three classes, namely *Pistacietea verae* (Nowak et al. 2024a), *Junipero-Pistacietea* (Zohary 1963) and *Quercetea brantii* Zohary 1963 (Ravanbakhsh et al. 2016; Hamzeh'ee 2017).

3) Steppes and other grasslands: Over half (52.0%) of the available plots encompass a diverse array of habitats broadly categorized as steppes and other grasslands. The term "steppe and other grasslands" is used as a broad sense (see Zohary 1973; Akhani 1998) and includes a variable array of physiognomy encompassing mesophytic to xerophytic, non-arboreal vegetation types covered by very dense to very sparse dwarf-shrubs, thorn-cushions or hemicryptophytes (excl. forests, woodlands, wet grasslands and halophytic communities) (see Akhani 1998; Ambarlı et al. 2018, 2020; Noroozi 2020; Talebi et al. 2021). This major habitat ranges from lowland arid/semi-arid playas up to 4,200 m a.s.l. in the alpine zone. We also included snowbed vegetation and other patchy montane mesophytic meadows/grasslands into this definition. Despite the presence of numerous transitional zones in the dataset and some azonal habitats such as chasmophytic vegetation, we propose three broad classes of steppes in Iran meeting general elevational gradients and main physiognomic-ecologic features.

3.1) Lowland steppes (7.9% of all plots; Figures 4, 5): This category sometimes called "*Artemisia* steppes" (see Zohary 1973; Akhani 1998; Ambarlı et al. 2018) comprises desertic and semi-desertic steppes of plains and undulating gentle slopes of vast areas of Iran and generally occurs below 1,200 m a.s.l. Lowland steppes are predominantly characterized by *Artemisia* spp., which are herbs or dwarf-shrubs of the *Asteraceae* family and typically have an aromatic and bluish-silvery appearance (Ambarlı et al. 2020) (Figure 7i). The density and floristic composition of these steppes are influenced by various factors, including edaphic conditions, annual precipitation, duration of the

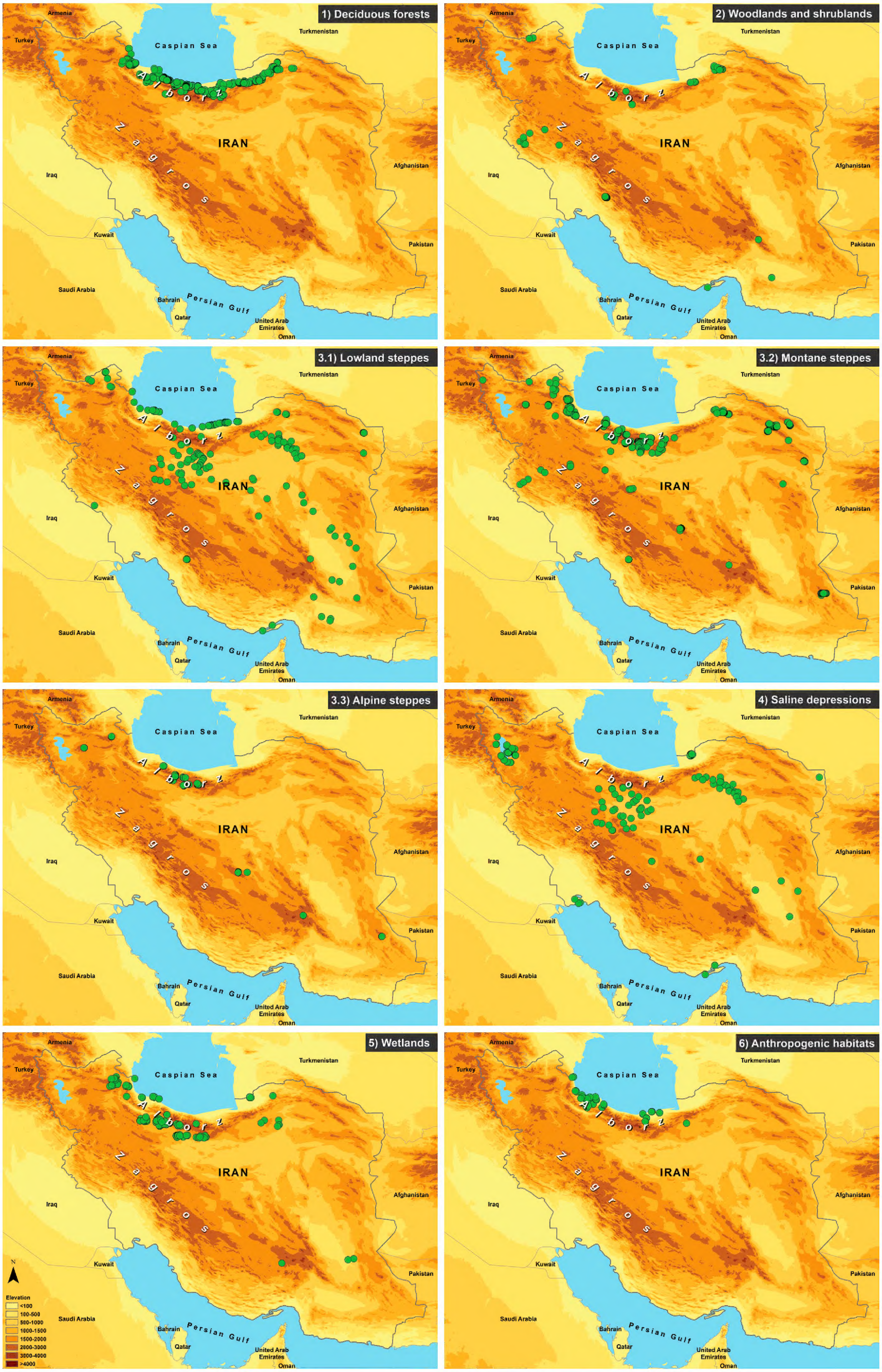

Figure 5. Spatial distribution of IranVeg plots across the major habitat types.

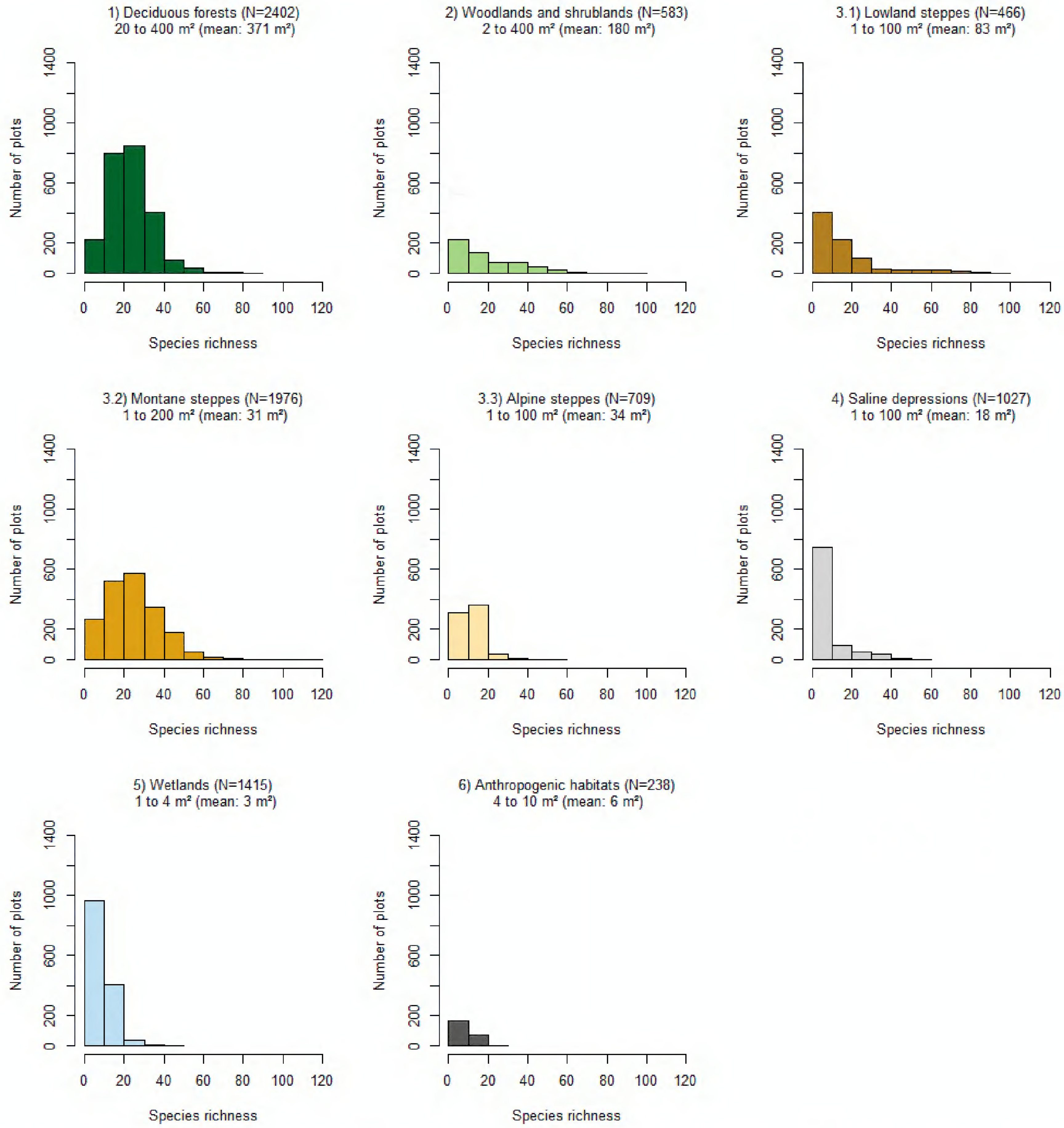

Figure 6. Frequency distribution of species richness across the major habitat types. Vegetation plots outside the central 95% percentile in size were excluded. N: Total number of plots.

dry season, altitude, and erosion (Frey and Probst 1986). However, this group of steppes received the lowest amount of precipitation (<100 mm to 300 mm) (see Assadi 1989; Akhani 1998). This habitat type also includes vast sand dune hills covered by a group of inland psammophytic vegetation of central Iran. Furthermore, coastal dune vegetation of southern Caspian shore including *Punica granatum* dwarf-shrublands are also included in this habitat type. Since there were only a limited number of central Iranian sand dune plots in our dataset, we included this kind of vegetation within lowland steppe (Figures 7j–l). Most plots of this group have a species richness ranging from 1 to 20 species per plot within areas of 1 to 100 m^2 with an average size of 83 m^2 (Figure 6), while a maximum of 86 species was found in a plot of 25 m^2.

Syntaxonomic classification of this habitat type is not fully dealt with. However, two main invalid phytosociological classes, *Artemisietea fragrantis anatolica* (Zohary 1973) and *Artemisietea sieberi*, including several valid and invalid associations, have been proposed from the lowland desertic steppes (see Zohary 1963, 1973; Asri 2003; Hamzeh'ee 2018). Furthermore, inland and coastal sand dunes were classified into three different classes, *Cakiletea maritimae*, *Artemisietea lerchianae* and *Stipagrostietea pennatae* (Zohary 1963; Asri 2003; Mahdavi et al. 2017).

3.2) Montane steppes (35.8% of all plots; Figures 4, 5): This category encompasses steppes and grasslands found within an altitude range of 1,200–3,500 m a.s.l. with comparatively higher precipitation (up to 400 mm). Among the studied plots, this habitat type possesses the highest species richness. The maximum richness level is reported from this group with 101 species in one plot of 25 m^2. Approximately half of the plots show species rich-

ness ranges between 20–40 while plot sizes vary from 1 to 200 m^2, with an average of 31 m^2 (Figure 6). This group includes subalpine tall herb communities of *Stipa* spp. and thorn-cushion dwarf shrub communities such as *Astragalus* spp., *Artemisia* spp., *Acantholimon* spp. and *Acanthophyllum* spp. (Figures 8a–b). Additionally, this group comprises plots from rocky and outcrop habitats (Figure 8c).

Notably, Klein (2001) and Noroozi et al. (2010, 2017) proposed a total of 38 valid associations, 11 alliances and four orders belonging to two classes, *Oxytropidetea persicae* (Klein 1982) and *Astragalo microcephali-Brometea tomentelli*, from this habitat type in their intensive phytosociological studies on montane and alpine zones of the Iranian mountains.

3.3) Alpine steppes (8.3% of all plots; Figures 4, 5): This group is distinguished by the high altitude, exceeding 3,500 m a.s.l., dominated by thorn-cushion grasslands, extending into the subnival zone and snowbed vegetation (Figure 8d–f). Hemicryptophytes dominate in the subnival zone and snowbed vegetation, while chamaephytes struggle to thrive due to the shortened growth period (Noroozi et al. 2010, 2014). Characterized by a notable proportion of endemic species, this habitat represents a unique ecosystem (Noroozi et al. 2010). Over 90% of the plots in this group demonstrate species richness varying from 1 to 20, covering plot sizes ranging from 1 to 100 m^2, with an average of 34 m^2 (Figure 6).

Valid syntaxa for the alpine steppes in northern and northwestern Iran have been proposed by Klein (1982) and Noroozi et al. (2010, 2014, 2017), including 14 associations, four alliances, three orders, and the class *Didymophyso aucheri-Dracocephaletea aucheri* (Noroozi et al. 2014).

4) Saline depressions: Saline and sabkha ecosystems, comprising 9.3% of all compiled plots, are mainly located at low and medium altitudes in coastal and inland salt depressions and playas in northern, southern and central Iran (Figures 4, 5). The plots often represent low species richness with fewer than 10 species per plot in sizes ranging from 1 to 100 m^2, with an average of 18 m^2 (Figure 6). This major habitat type includes the central Iranian great deserts "Dasht-e Kavir" and "Kavir-e Lut", the salt flats and salt marshes of the Urmia lake, the SE Caspian Sea, the Khuzestan Plain and coastal parts of the Persian Gulf and Oman Sea (Akhani 2004; Akhani and Samadi 2015) (Figure 8g–i). The formation of these saline habitats in Iran is attributed to several factors, including the recycling and accumulation of salts in the soil due to low rainfall, river flow, salt spray in littoral and marsh zones, as well as geological origin (Akhani 2004). Salinity and moisture are two significant ecological drivers shaping zonation patterns in halophytic vegetation in these areas (Akhani 2004, 2006). Saline depressions are characterized by structurally uniform plant communities with low species diversity (Asri 2003; Akhani 2004, 2006; Mehrabian et al. 2009; Ghorbanalizadeh et al. 2020). Genera such as *Anabasis*, *Atriplex*, *Climacoptera*, *Halothamnus*, *Limonium*, *Salsola* and *Suaeda* are among the most important halophytic genera in the saline habitats of Iran (Akhani and Ghorbanli 1993; Asri and Ghorbanli 1997; Akhani 2004). Several plant communities have so far been proposed for the saline depressions of Iran belonging to the classes *Thero-Salicornietea*, *Kalidietea foliati*, *Salicornietea fruticosae*, *Molinio-Arrhenatheretea*, *Tamaricetea arceuthoidis* and *Caroxylo-Climacopteretea* (e.g. Akhani and Mucina 2015; Ghorbanalizadeh et al. 2020).

5) Wetlands: A total of 12.2% of the compiled plots belong to wetland habitats (Figures 4, 5). Most plots show poor richness with fewer than 10 species per plot in sizes ranging from 1 to 4 m^2, and an average size of 3 m^2. The maximum richness recorded was 38 species in a plot of 4 m^2 (Figure 6). We use the term "wetlands" for a wide range of habitats, from freshwater lakes, rivers and riparian habitats with open water to montane mires and springs as well as wet meadows with inundated soil (see Sharifi et al. 2013; Jalili et al. 2014; Naqinezhad et al. 2021) (Figure 8j–l). One of the outstanding features of the dry Irano-Turanian montane steppes is that they embrace "green islands" of mires/springs in their matrix. These wet patches are important areas to be considered for conservation because they are refugia for many endemics/near endemics and are diagnostic species in these habitats. These include *Cerastium persicum*, *Cirsium glaberrimum*, *Deyeuxia parsana*, *Eleocharis palustris* subsp. *iranica*, *Ligularia persica*, *Myosotis sylvatica* subsp. *rivularis*, *Ranunculus amblyolobus*, *R. kotschyi*, and *Swertia longifolia* (Naqinezhad et al. 2009, 2021; Kamrani et al. 2011). The only valid publication of syntaxa from this group is by Naqinezhad et al. (2021) on mires and spring habitats of the Alborz Mountains, reporting 11 associations, three alliances, three order and three classes, *Montio-Cardaminetea*, *Scheuchzerio-Caricetea nigrae* and *Molinio-Arrhenatheretea*. There are plots of open water habitats characterized by aquatic floating and submerged plants (e.g. *Nelumbo nucifera*, *Myriophyllum spicatum*, *Najas minor*, *Ceratophyllum demersum*, *Potamogeton* spp. and *Lemna* spp.) and emergent plants (e.g. *Phragmites australis*, *Schoenoplectus litoralis* and *Typha* spp.) from the phytosociological classes *Lemnetea*, *Potamogetonetea* and *Phragmito-Magnocaricetea* (Asri and Eftekhari 2002; Asri and Moradi 2006; Asri et al. 2007; Maghsoudi et al. 2015; Hamedani et al. 2017).

6) Anthropogenic habitats: This major habitat type encompasses all plots collected from habitats strongly modified by humans, including arable fields and urban green spaces, currently accounting for 2.9% of plots (Figures 4, 5). The sizes of the plots were 4 or 10 m^2 and more than 50% of the plots of this group contained fewer than 10 species. The maximum richness of 18 species was recorded in 10 m^2 of an urban ruderal community (Figure 6). Both native and alien ruderal species are frequent in this group of plots (Figure 8m). From a phytosociological point of view, most of the syntaxa proposed for this group have been invalidly proposed, and further studies are needed to explore the syntaxonomic position of these habitats in Iran. However, one valid class of *Bidentetea tripartitae* (Asri and Eftekhari 2002) and three invalid classes *Panicetea segetalis*, *Secalinetea iranica* and *Ruderetea* (Zohary 1963) were proposed for this type of vegetation.

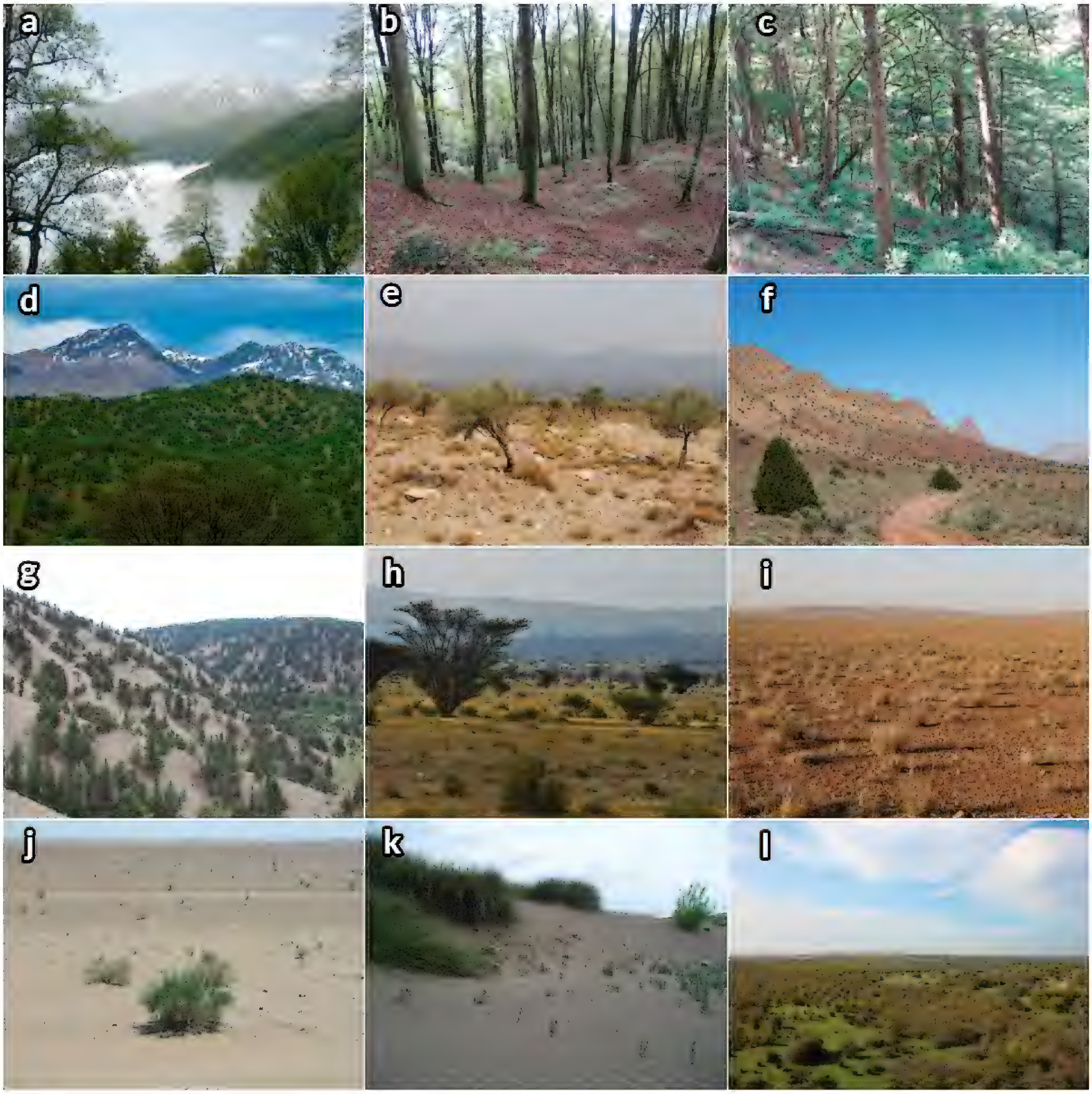

Figure 7. Photos of the major habitat types of Iran. Deciduous forests: a) Hyrcanian forest landscape, northern Iran; b) beech forests of the Hyrcanian ecoregion, northern Iran; c) unique yew (*Taxus baccata*) stand in the Hyrcanian forest, northern Iran; woodlands and shrublands: d) *Quercus* steppe woodlands in Zagros, western Iran; e) pistachio-almond steppe shrublands in Kerman, southern Iran; f) *Juniperus polycarpos* woodlands in Semnan, northern Iran; g) *Cupressus sempervirens* woodlands in Hassanabad-Chalus, northern Iran; h) savanna-like woodlands, southern Iran; lowland steppes: i) *Artemisia* community in central Iran; j) inland sand dunes in central Iran; k) coastal dunes in Miankaleh Biosphere Reserve, northern Iran; l) *Punica granatum* coastal shrublands in Miankaleh Biosphere Reserve, northern Iran. Photos by A. Naqinezhad (a–b, d–g, i, k–l); A. Talebi (h, j); O. Esmailzadeh (c).

Conclusions and future perspectives

The IranVeg database stands as a vital repository, not only providing a snapshot of Iran's current and past vegetation but also laying the groundwork for future ecological research and conservation endeavors. While certain vegetation types and regions have received considerable attention, others remain poorly studied or are completely absent from our dataset. For instance, extensive areas across the Alborz Mountain range, particularly near the capital city, Tehran, have been extensively sampled due to their proximity to research centers, resulting in relatively well studied vegetation types in these regions. Conversely, vast stretches of land (see Figures 1, 5) lack even a single plot, highlighting significant gaps in our understanding of certain habitats and regions.

Several factors contribute to this disparity in data coverage. Challenges such as limited funding and logistical difficulties in remote areas are particularly prevalent, especially for oak woodland communities in the massive mountains of Zagros and savanna-like grasslands in the

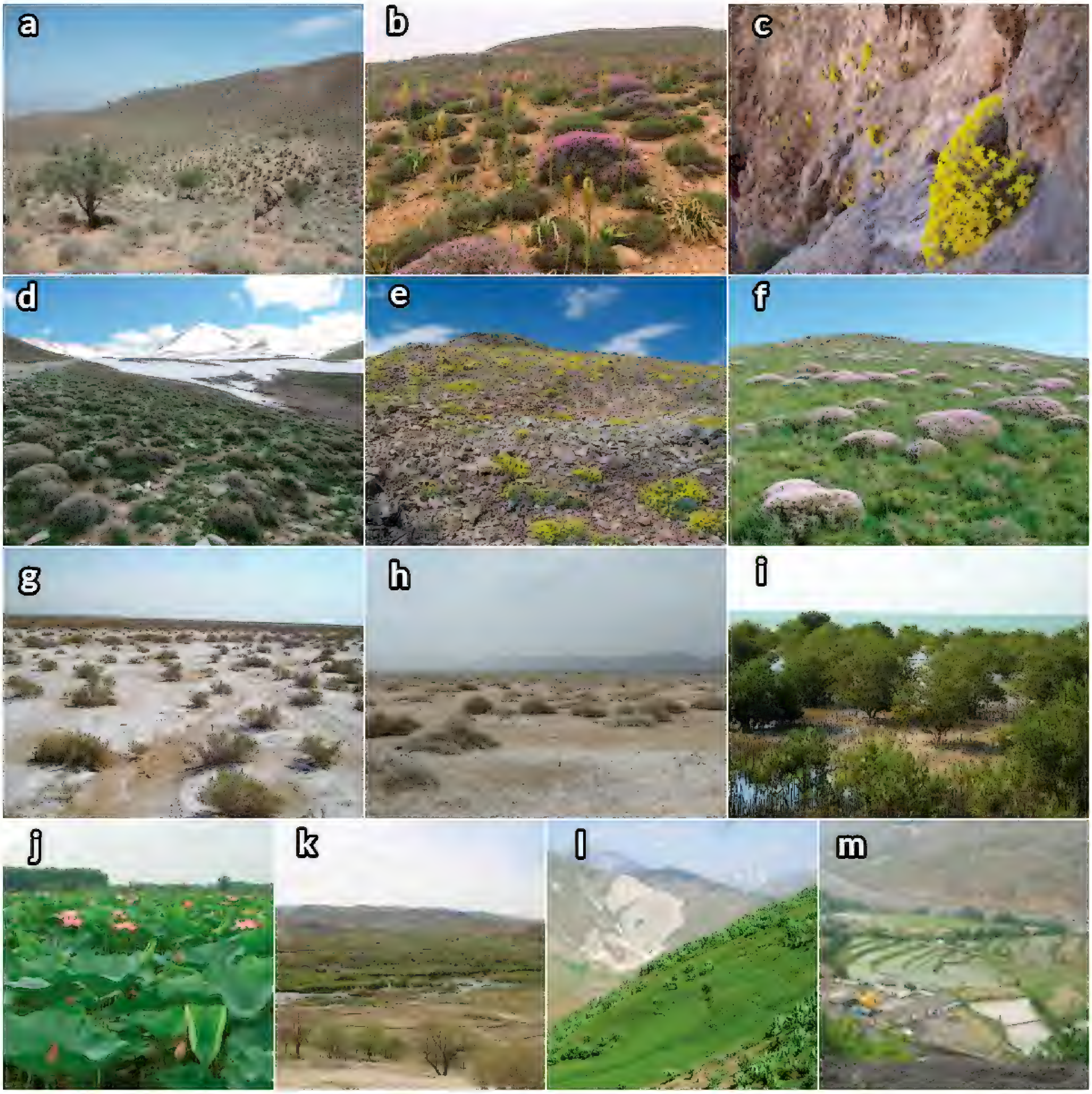

Figure 8. Photos of the major habitat types of Iran. Montane steppes: a) montane steppe in Taftan Mts., southeastern Iran; b) thorn-cushion grasslands in Baharkish Mts., eastern Iran; c) rock vegetation of *Dionysia* in Zagros Mts, western Iran; alpine steppe: d) alpine vegetations of Sahand Mts., northwestern Iran; e) alpine-subnival screes in Tuchal Mts., central Alborz, northern Iran; f) thorn-cushion grasslands in alpine zone in Bozgush Mts., northwestern Iran; saline depressions: g) *Halocnemum strobilaceum* communities in Mond Protected Area, Bushehr, southern Iran; h) *Halocnemum-Siedlitzia* communities of southern Iran; i) mangrove forests in Bushehr, southern Iran; wetland: j) *Nelumbo nucifera* community in the Anzali Ramsar Site, northern Iran; k) riparian habitats in Kohgiluyeh and Boyer Ahmad, western Iran; l) montane mires in the Alborz Mountains, northern Iran; anthropogenic habitats: m) rice fields of northern Iran. Photos by A. Naqinezhad (a, g, i–m); J. Noroozi (c–f); A. Talebi (h); S. Rahmanian (b).

subtropical Saharo-Sindian regions of southern Iran. Furthermore, decreasing interest among scholars in vegetation ecology topics has hindered comprehensive vegetation studies in Iran. Additionally, barriers such as insufficient incorporation of vegetation data in land use planning and limited emphasis on vegetation ecology in university curricula further exacerbate the situation.

To address these challenges, it is imperative to emphasize the importance of vegetation data, both nationally and internationally. Expanding and enhancing vegetation data from Iran is essential for several reasons. Locally, such data are invaluable for diversity analyses, vegetation classification, landscape planning, land management, biodiversity conservation, and ecosystem restoration efforts. Internationally, Iran's diverse vegetation serves as a crucial component of global biodiversity and ecosystem function. Thus, better understanding and documenting Iran's vegetation contribute not only to national conservation goals but also to broader global biodiversity conservation efforts. These kinds of datasets play a pivotal role in fostering macroecological investigations on

a continental or global scale. Notably, selected datasets from this Iranian repository have already been utilized in macroecology research through opt-in projects registered in sPlot (Bruelheide et al. 2019; Sabatini et al. 2021) and GrassPlot (Dengler et al. 2018, 2020; Biurrun et al. 2019, 2021; Dembicz et al. 2021a, 2021b; Zhang et al. 2021; Ulrich et al. 2022) as well as other large scale regional analyses (Loidi et al. 2021; Naqinezhad et al. 2021, 2022; Nowak et al. 2024a, b; Novák et al. 2023; Gallou et al. 2023; Sękiewicz et al. 2024).

A total of 31 phytosociological classes, along with numerous subordinate syntaxa, have been proposed for the vegetation types in Iran. However, only a small fraction of these proposed syntaxa have been validly published. Considerable effort is still required to complement and validate the remaining syntaxa. The slow progress in the syntaxonomic classification of Iran can be attributed to several factors. Primarily, the standardization of phytosociological work in the country has lagged behind the international pace. Moreover, many Iranian authors are reluctant to follow standard phytosociological nomenclature, believing that without comprehensive surveys and further data collection, any decision regarding the validation of proposed syntaxa would be premature. Consequently, many of these proposed syntaxa have been regarded as provisional. In this paper, we do not aim to validate these syntaxa, as that would require a separate and extensive effort, particularly given the complex vegetation structure and vast geographical scope of Iran.

While our database represents a significant achievement, it is important to acknowledge its limitations. We cannot claim to have digitized 100% of all relevant data to date. Indeed, a considerable portion of vegetation data likely remains undocumented in publications, theses, and personal notebooks. To provide a more accurate assessment, future efforts should aim to estimate the fraction of existing data captured in our database compared to data available elsewhere. Moreover, it is essential to recognize other major databases in the region, such as those for Turkey (Kavgaci 2016; Uğurlu 2016; Uğurlu and Isik 2020; Güler 2023) and Middle Asia (Nowak and Nobis 2019; Nowak et al. 2024b), which may have larger datasets covering smaller areas. Acknowledging and collaborating with these initiatives can foster a more comprehensive understanding of vegetation across Southwest and Middle Asia.

In conclusion, IranVeg represents a collaborative effort toward understanding and conserving Iran's botanical heritage. Moving forward, continued collaboration among researchers and the development of a cooperative network are crucial for further enhancing the database and addressing the complex ecological challenges facing Iran and the broader region. Researchers holding relevant vegetation data are encouraged to contribute to IranVeg, while those seeking to utilize the database for research purposes are welcome to submit proposals to the custodians. The proposal could be submitted by one or a group of leading researchers who are responsible for collected data. The most important benefits of contributing plots into this national database are opt-in options to the papers extracted from this collective national database and also own access of the contributing authors to the full database as this is the case in other collaborative databases such as GrassPlot (Dengler et al. 2018, 2020; Biurrun et al. 2019) or sPlot (Bruelheide et al. 2019; Sabatini et al. 2021). By leveraging shared knowledge and resources, we can advance our understanding of Iran's vegetation and contribute to global conservation efforts.

Data availability

Access to the database is restricted; however, interested researchers may obtain the data by submitting a formal request to the database manager.

Author contributions

AN, JN and PM perceived the idea and registered the preliminary dataset. AN, JN and SR coordinate the IranVeg Consortium as Custodian and Deputy Custodian, respectively. SR aggregated new datasets, performed analysis and prepared the draft with main contribution by AN. SST aggregated data. JN, HG, BH, YA, and AT read and approved the final version of the article. The other co-authors have collected the field data and read/modified the final version.

Acknowledgments

A considerable part of the plots in IranVeg were contributed by all the published materials of the following colleagues: Jean Cloud Klein, Jean Léonard, Hossein Akhani, Farhang Assadollahi, Mostafa Naderi, Mostafa Nemati Peykani, Asadollah Mataji, Amirhossein Kashypazha, Nayereh Rastin, Hassan Nazarian, Ahmad Ahmadi, Hassan Dorostkar, Khadijeh Salari Nik, Jinus Jashni, Ahmad Mossadegh, Gholamreza Bakhshi Khaniki, Mohammad Hossein Djazirei and Mohammadreza Borji.

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Supplementary material

Supplementary material 1
Data sources utilized in the IranVeg database (*.pdf)
Link: https://doi.org/10.3897/VCS.114081.suppl1